LED WATCH

BY JAMES BRODRICK

It's no secret that lighting designers and buyers currently have problems comparing LED products to traditional light sources based on manufacturers' reported efficacy ratings. Many LED fixtures reference luminous efficacy (lumens per watt) figures in marketing and product information. The challenge for the lighting specifier is understanding what those numbers mean.

Unfortunately, the market is currently characterized by a patchwork of approaches: some manufacturers quote LED device efficacy, some list incandescent "equivalency" and a few cite luminaire efficacy. Why all the confusion? Shouldn't LED products be measured the same as traditional light sources? Yes and no.

A DIFFERENT METRIC

For many years, lamp ratings have been the bedrock of lighting performance evaluation. Incandescent, fluorescent and HID lamps are tested and rated for luminous flux under standard conditions, independent of the fixtures they'll be used in. This allows easy comparisons of light source energy efficiency, based on *system efficacy*—the rated light output of the lamp (in lumens) divided by the power input to the lamp and ballast system (in watts).

The emergence of LEDs as a general light source changes the picture because the system efficacy rating is not appropriate for LEDs. The only way to know how much light an LED fixture (or any fixture) produces in a sure manner is to measure the complete luminaire. This provides total lumens and total wattage, resulting in a measure of *luminaire efficacy* in lumens per watt.

The importance of luminaire efficacy is gaining recognition across the lighting industry. In the July 2007 issue of *Leukos*, editor David L. DiLaura wrote an editorial in which he stated: "Luminaire efficacy accounts for the difficulty of using all the lumens generated, however high the source efficacy. Naturally, poor luminaire optics can have a large canceling effect on high-source efficacy and produce low luminaire efficacy. This wide view of assessing lighting system performance is a welcome development, if only because it will make the energy comparison of lighting equipment easier and more certain. Naturally, what counts are the lumens that leave a luminaire per watt of input power. Looking only at source efficacy can be very misleading."

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Luminaire efficacy provides a more appropriate measure of LED performance. The reasons are inherent in the technology:

1. Luminous flux rating of LED devices (as given on LED datasheets, for example) is conducted under conditions that differ significantly from normal operation as a light source. It's based on a very short (<1 sec) pulse, at low device temperature, and without a heat sink. Further, the specific test parameters (drive current, temperature, pulse duration) vary by manufacturer.
2. Measurement of the LED light source separate from the fixture will not yield accurate results, because multiple LED devices are often arrayed together to provide adequate light. Due to thermal and electrical interactions, the light output of the LEDs is not always additive.
3. LED performance is significantly affected by elevated temperature. LED devices generate heat that is typically removed by an external heat sink, which is often designed into the luminaire itself.

Separating the light source from its heat sink will significantly impact test results.

4. It may be impractical or cost-prohibitive to separate the light source from the luminaire because the LEDs may be integrated in such a way as to make separation physically difficult or impossible.

NEW STANDARD

The soon-to-be published IESNA LM-79, "Approved Method for the Electrical and Photometric Testing of Solid-State Lighting Devices," specifies a standard test method for solid-state lighting sources based on luminaire efficacy. Among other specifications, LM-79 provides test procedures for photometric measurements using an integrating sphere, goniophotometer and spectroradiometer. The LM-79 tests provide total luminous flux (lumens), luminous intensity (candelas) in one or more directions, chromaticity coordinates, correlated color temperature (CCT) and color rendering index (CRI). The new test procedure is expected to be finalized and published by the IESNA in early 2008.

LM-79 addresses only solid-state lighting devices, not incandescent, fluorescent or HID lamps or fixtures. But wouldn't luminaire efficacy be a better metric for all? Given that LED and traditional light sources are tested differently, how can we make reasonable comparisons of luminaires using different light sources?

Since LEDs cannot be tested for system efficacy, luminaire efficacy is the logical metric to use for direct comparisons of different light sources. Most commercial or specification-grade luminaires are photometered according to standard

	DOE CALiPER Data*			Luminaire Manufacturer Information	
	Total Watts	Output Lumens	**Luminaire Efficacy (lm/W)**	Published *Lamp* Lumens	Implied ***System*** Efficacy (lm/W)
Downlight 1	12.8	346	**27**	900	**69**
Downlight 2	12.2	514	**42**	860	**66**
Undercabinet 1	18.9	689	**36**	2100	**96**
Undercabinet 2	11.69	237	**20**	690	**53**

*CALIPER photometric measurements on ENERGY STAR qualified fluorescent products (EPA Residential Light Fixtures Program). Full reports for each fixture tested are available at *http://www.netl.doe.gov/ssl/comm_testing.htm*.

Figure 1. DOE CALiPER Benchmark Tests on Fluorescent Fixtures.

test procedures published by the IESNA specific to the light source used (e.g., LM-41-98 for indoor fluorescent luminaires, or LM-46-04 for HID and incandescent indoor luminaires). The results are published in a standard format (as defined by LM-63-2002), which allows comparison across different light sources. However, photometric reports are not available for all types of fixtures.

In these cases, an estimate of the fixture efficiency must be made in order to get a reasonable comparison of LED and traditional luminaire performance. To remove some of the guess work, DOE's CALiPER program has begun benchmark testing of CFL and linear fluorescent luminaires to measure luminaire efficacy. **Figure 1** shows test results for several fluorescent-based fixtures, indicating the significant differences between lamp ratings and luminaire performance. In one case, a fluorescent fixture with high system efficacy of 96 lumens per watt measured only 36 lumens per watt when tested for luminaire efficacy. The stated output of 2,100 lumens measured under 700 lumens. While a very small sample, evidence from other sources indicates this degree of fixture optical losses (40-60 percent) is not atypical. Obviously, luminaire efficacy can differ greatly from system efficacy.

USING 'GAME' PERFORMANCE

To use a sports analogy, system efficacy is like a football player's running speed in the 40-yard dash while wearing running shoes, gym shorts and a t-shirt; luminaire efficacy is more like his speed when encumbered by spiked shoes, pads and the helmet he will wear in an actual game. Because we are interested in the actual "game" performance of lighting devices, it makes sense to use luminaire efficacy as the standard for comparison.

Good lighting and energy efficiency decisions must be based on appropriate comparisons of various light sources. Comparing LED luminaire efficacy to traditional system efficacy will give inaccurate results because the latter does not include optical or thermal losses. To ensure you're comparing apples to apples, compare LED and traditional light sources on the basis of luminaire efficacy, based on photometric reports provided by independent testing laboratories. As DiLaura states, this approach will make the energy comparison of lighting equipment easier and more certain.

James Brodrick is the lighting program manager for the U.S. Department of Energy Building Technologies Program. The Department's national strategy to guide high efficiency, high-performance solid-state lighting products from laboratory to market draws on key partnerships with the lighting industry, research community, standards organizations, energy-efficiency programs, utilities and many other voices for efficiency.